# CLAIMS

1. A plasma reactor to generate power and novel hydrogen species and compositions of matter comprising new forms of hydrogen via the catalysis of atomic hydrogen and to generate a plasma and a source of light such as high energy light, extreme ultraviolet light and ultraviolet light, via the catalysis of atomic hydrogen, the reactor comprising

 a plasma forming energy cell for the catalysis of atomic hydrogen to form novel hydrogen species and compositions of matter comprising new forms of hydrogen,

 a source of catalyst for catalyzing the reaction of atomic hydrogen to form lower-energy hydrogen and release energy,

 a source of atomic hydrogen, and

 a source of intermittent or pulsed power to at least partially maintain the plasma.

2. The reactor of claim 1 wherein the cell comprises at least one of the group of a microwave cell, plasma torch cell, radio frequency (RF) cell, glow discharge cell, barrier electrode cell, plasma electrolysis cell, a pressurized gas cell, filament cell or rt-plasma cell, and a combination of at least one of a glow discharge cell, a microwave cell, and an RF plasma cell.

3. The reactor of claim 1 wherein the intermittent or pulsed power source reduces the input power.

4. The reactor of claim 1 wherein the intermittent or pulsed power source provides a time period wherein the field is set to a desired strength by an offset DC, audio, RF, or microwave voltage or electric and magnetic fields.

5. The reactor of claim 4 wherein the field is set to a desired strength during a time period by an offset DC, audio, RF, or microwave voltage or electric and magnetic fields that is below that required to maintain a discharge.

6. The reactor of claim 4 wherein the desired field strength during a low-field or nondischarge period optimizes the energy match between the catalyst and the atomic hydrogen.

7. The reactor of claim 1 wherein the intermittent or pulsed power source further comprises a means to adjust the pulse frequency and duty cycle to optimize the power balance.

8. The reactor of claim 7 wherein the pulse frequency and duty cycle is adjusted to optimize the power balance by optimizing the reaction rate versus the input power.

9. The reactor of claim 9 wherein the pulse frequency and duty cycle is adjusted to optimize the power balance by optimizing the reaction rate versus the input power by controlling the amount of catalyst and atomic hydrogen generated by the discharge decay during the low-field or nondischarge period wherein the concentrations are dependent on the pulse frequency, duty cycle, and the rate of plasma decay.

10. The reactor of claim 107 wherein the catalyst is selected from the group of $He^+$, $Ne^+$, and $Ar^+$.

11. The reactor of claim 1 wherein the intermittent or pulsed frequency is of about 0.1 Hz to about 100 MHz.

12. The reactor of claim 1 wherein the intermittent or pulsed frequency is faster than the time for substantial atomic hydrogen recombination to molecular hydrogen.

13. The reactor of claim 1 wherein the intermittent or pulsed frequency is within the range of about 1 to about 1000 Hz and the duty cycle is about 0.001% to about 95%.

14. The reactor of claim 1 wherein the intermittent or pulsed duty cycle is about 0.1% to about 50%.

15. The reactor of claim 1 wherein the power is alternating and the frequency of the alternating power may be within the range of about 0.001 Hz to 100 GHz.

16. The reactor of claim 1 wherein the intermittent or pulsed frequency is within the range of about 60 Hz to 10 GHz.

17. The reactor of claim 1 wherein the intermittent or pulsed frequency is within the range of about 10 MHz to 10 GHz.

18. The reactor of claim 1 that comprises two electrodes wherein one or more electrodes are at least one of in direct contact with the plasma, and separated from the plasma by a dielectric barrier.

19. The reactor of claim 18 wherein the peak voltage is within the range of at least one of about 1 V to 10 MV, about 10 V to 100 kV, and about 100 V to 500 V.

20. The reactor of claim 1 that further comprises at least one antenna to deliver power to the plasma.

21. The reactor of claim 1 wherein the catalyst comprises at least one selected from the group of $He^+$, $Ne^+$, and $Ar^+$ wherein the ionized catalyst ion is generated from the corresponding atom by a plasma created by methods such as a glow, inductively or capacitively coupled RF, or microwave discharge.

22. The reactor of claim 1 wherein hydrogen pressure of the plasma cell is at least one of within the range of about 1 mTorr to 10,000 Torr, about 10 mTorr to 100 Torr, and about 10 mTorr to 10 Torr.

23. The reactor of claim 1 comprising a microwave plasma cell for the catalysis of atomic hydrogen to form increased-binding-energy-hydrogen species and increased-binding-energy-hydrogen compounds comprising a vessel having a chamber capable of containing a vacuum or pressures greater than atmospheric, a

source of atomic hydrogen, a source of pulsed or intermittent microwave power to form a plasma, and a catalyst capable of providing a net enthalpy of reaction of $m/2 \cdot 27.2 \pm 0.5\ eV$ where $m$ is an integer, preferably $m$ is an integer less than 400.

24. The reactor of claim 1 wherein the source of pulsed or intermittent microwave power comprises at least one of the group of traveling wave tubes, klystrons, magnetrons, cyclotron resonance masers, gyrotrons, and free electron lasers.

25. The reactor of claim 1 wherein the source of pulsed or intermittent microwave power comprises an amplifier to amplify the microwave power.

26. The reactor of claim 1 wherein the source of pulsed or intermittent microwave power is delivered by at least one of a waveguide, coaxial cable, and an antenna.

27. The reactor of claim 1 wherein the source of pulsed or intermittent microwave power comprises at least one of a magnetron with a pulsed high voltage to the magnetron and a pulsed magnetron current.

28. The reactor of claim 27 wherein the pulsed magnetron current is supplied by a pulse of electrons from an electron source.

29. The reactor of claim 28 wherein the source of pulses of electrons from an electron source is an electron gun.

30. The reactor of claim 1 wherein the source of pulsed or intermittent microwave power comprises a frequency of the power may be within the range of at least one of about 100 MHz to 100 GHz, about 100 MHz to 10 GHz, about 1 GHz to 10 GHz, and about 2.4 GHz $\pm$ 1 GHz.

31. The reactor of claim 1 wherein the pulse frequency is at least one of the range of about 0.1 Hz to about 100 MHz, about 10 to about 10,000 Hz, and about 100 to about 1000 Hz.

32. The reactor of claim 1 wherein the duty cycle is at least one of the range of about 0.001% to about 95%, and about 0.1% to about 10%.

33. The reactor claim 1 wherein the peak power density of the pulses into the plasma is at least one of the range of about 1 $W/cm^3$ to 1 $GW/cm^3$, about 10 $W/cm^3$ to 10 $MW/cm^3$, and about 100 $W/cm^3$ to 10 $kW/cm^3$.

34. The reactor of claim 1 wherein the average power density of the pulses into the plasma is at least one of the range of about 0.001 $W/cm^3$ to 1 $kW/cm^3$,about 0.1 $W/cm^3$ to 100 $W/cm^3$, and about 1 $W/cm^3$ to 10 $W/cm^3$.

35. The reactor of claim 1 comprising at least one of a capacitively and inductively coupled radio frequency (RF) plasma cell for the catalysis of atomic hydrogen to form increased-binding-energy-hydrogen species and increased-binding-energy-hydrogen compounds comprising a vessel having a chamber capable of containing a vacuum or pressures greater than atmospheric, a source of atomic hydrogen, a source of pulsed or intermittent RF power to form a plasma, and a catalyst capable of providing a net enthalpy of reaction of $m/2 \cdot 27.2 \pm 0.5\ eV$ where $m$ is an integer, preferably $m$ is an integer less than 400.

36. The reactor of claim 35 comprising at least two electrodes and a pulsed or intermittent RF generator wherein the source of RF power comprises the electrodes driven by the RF generator.

37. The reactor of claim 35 comprising a source coil that is either internal or external to a cell wall which permits RF power to couple to the plasma formed in the cell, a conducting cell wall is one of grounded and floating, and n RF generator which drives the coil by at least one of inductively and capacitively coupling RF power to the cell plasma.

38. The reactor of claim 35 wherein the RF frequency is at least one of the range of about 100 Hz to about 100 MHz, about 1 kHz to about 50 MHz, andabout 13.56

MHz ± 50 MHz.

39. The reactor of claim 35 wherein the pulse frequency is at least one of the range of about 0.1 Hz to about 100 MHz, about 10 Hz to about 10 MHz, and about 100 Hz to about 1 MHz.

40. The reactor of claim 35 wherein the duty cycle is at least one of the range of about 0.001% to about 95%, and about 0.1% to about 10%.

41. The reactor of claim 35 wherein the peak power density of the pulses into the plasma is at least one of the range of about 1 $W/cm^3$ to 1 $GW/cm^3$, about 10 $W/cm^3$ to 10 $MW/cm^3$, and about 100 $W/cm^3$ to 10 $kW/cm^3$.

42. The reactor of claim 35 wherein the average power density of the pulses into the plasma is at least one of the range of about 0.001 $W/cm^3$ to 1 $kW/cm^3$, about 0.1 $W/cm^3$ to 100 $W/cm^3$, and about 1 $W/cm^3$ to 10 $W/cm^3$.

43. The reactor of claim 1 comprising an inductively coupled plasma source comprising a toroidal plasma system such as the Astron system of Astex Corporation described in US Patent No. 6,150,628.

44. The reactor of claim 43, comprising a toroidal plasma system comprising a primary of a transformer circuit.

45. The reactor of claim 44 further comprising a radio frequency power supply that drives the primary of the transformer circuit.

46. The reactor of claim 44 wherein the plasma is a closed loop which acts at as a secondary of the transformer circuit.

47. The reactor of claim 44 wherein the RF frequency is at least one of within the range of about 100 Hz to about 100 GHz, about 100 MHz, about 13.56 MHz ± 50 MHz, and about 2.4 GHz ± 1 GHz.

48. The reactor of claim 44 wherein the pulse frequency is at least one of within the range of about 0.1 Hz to about 100 MHz, about 10 Hz to about 10 MHz, and about 100 Hz to about 1 MHz.

49. The reactor of claim 44 wherein the duty cycle is at least one of within the range of about 0.001% to about 95%, and about 0.1% to about 10%.

50. The reactor of claim 44 wherein the peak power density of the pulses into the plasma is at least one of within the range of about 1 $W/cm^3$ to 1 $GW/cm^3$, about 10 $W/cm^3$ to 10 $MW/cm^3$, and about 100 $W/cm^3$ to 10 $kW/cm^3$.

51. The reactor of claim 44 wherein the average power density of the pulses into the plasma is at least one of within the range of about 0.001 $W/cm^3$ to 1 $kW/cm^3$, about 0.1 $W/cm^3$ to 100 $W/cm^3$, and about 1 $W/cm^3$ to 10 $W/cm^3$.

52. The reactor of claim 1 comprising a discharge cell wherein the discharge voltage is within the range of about 1000 to about 50,000 volts and the intermittent or pulsed discharge current is within the range of about 1 $\mu$A to about 1 A.

53. The reactor of claim 52 having an offset voltage during the nonpeak-power phase of the intermittent or pulsed power that is within the range of about 0.5 to about 500 V.

54. The reactor of claim 53 wherein the offset voltage is set to provide a field that is at least one of within the range of about 0.1 V/cm to about 50 V/cm, and about 1 V/cm to about 10 V/cm.

55. The reactor of claim 52 having a peak voltage that is at least one of within the range of about 1 V to 10 MV, about 10 V to 100 kV, and about 100 V to 500 V.

56. The reactor of claim 52 wherein the desired field strength during a low-field or nondischarge period optimizes the energy match between the catalyst and the

atomic hydrogen.

57. The reactor of claim 52 wherein the intermittent or pulsed power source further comprises a means to adjust the pulse frequency and duty cycle to optimize the power balance.

58. The reactor of claim 57 wherein the pulse frequency and duty cycle is adjusted to optimize the power balance by optimizing the reaction rate versus the input power.

59. The reactor of claim 58 wherein the pulse frequency and duty cycle is adjusted to optimize the power balance by optimizing the reaction rate versus the input power by controlling the amount of catalyst and atomic hydrogen generated by the discharge decay during the low-field or nondischarge period wherein the concentrations are dependent on the pulse frequency, duty cycle, and the rate of plasma decay.

60. The reactor of claim 59 wherein the catalyst is selected from the group of $He^+$, $Ne^+$, and $Ar^+$.

61. The reactor of claim 52 wherein the intermittent or pulsed frequency is of about 0.1 Hz to about 100 MHz.

62. The reactor of claim 52 wherein the intermittent or pulsed frequency is faster than the time for substantial atomic hydrogen recombination to molecular hydrogen.

63. The reactor of claim 52 wherein the intermittent or pulsed frequency is within the range of about 1 to about 200 Hz, the duty cycle is within the range of about 0.1% to about 95%.

64. The reactor of claim 52 wherein the intermittent or pulsed duty cycle is about 1% to about 50%.

65. The reactor of claim 52 wherein the power may be applied as an alternating

current (AC).

66. The reactor of claim 65 wherein the frequency is at least one of within the range of about 0.001 Hz to 1 GHz, about 60 Hz to 100 MHz, and about 10 to 100 MHz.

67. The reactor of claim 66 that comprises two electrodes wherein one or more electrodes are at least one of in direct contact with the plasma, and separated from the plasma by a dielectric barrier.

68. The reactor of claim 67 wherein the peak voltage is within the range of about at least one of about 1 V to 10 MV, about 10 V to 100 kV, and about 100 V to 500 V.

69. The barrier electrode plasma cell of claim 67 wherein the frequency is at least one of within the range of about 100 Hz to about 10 GHz, about 1 kHz to about 1 MHz, and about 5-10 kHz.

70. The barrier electrode plasma cell of claim 67 wherein the voltage is at least one of within the range of about 100 V to about 1 MV, about 1 kV to about 100 kV, and about 5 to about 10 kV.

71. The reactor of claim 1 comprising a pulsed plasma electrolysis cell wherein the discharge voltage is within the range of about 1000 to about 50,000 volts, and the discharge current into the electrolyte is within the range of about 1 $\mu A/cm^3$ to about 1 $A/cm^3$.

72. The reactor of claim 71 having an offset voltage that is below that which causes electrolysis.

73. The reactor of claim 72 wherein the offset voltage is within the range of about 0.001 to about 1.4 V.

74. The reactor of claim 71 wherein the peak voltage is at least one of within the

range of about 1 V to 10 MV, about 2 V to 100 kV, and about 2 V to 1 kV.

75. The reactor of claim 71 wherein the pulse frequency is at least one of within the range of about 0.1 Hz to about 100 MHz, and about 1 to about 200 Hz.

76. The reactor of claim 71 wherein the duty cycle is at least one of within the range of about 0.1% to about 95%, and about 1% to about 50%.

77. The reactor of claim 1 comprising a filament cell wherein the field from the filament alternates from a higher to lower value during pulsing.

78. The reactor of claim 77 wherein the peak field is at least one of within the range of about 0.1 V/cm to 1000 V/cm, and about 1 V/cm to 10 V/cm.

79. The reactor of claim 77 wherein the off-peak field is at least one of within the range of about 0.1 V to 100 V/cm, and about 0.1 V to 1 V/cm.

80. The reactor of claim 77 wherein the pulse frequency is at least one of within the range of about 0.1 Hz to about 100 MHz, and about 1 to about 200 Hz.

81. The reactor of claim 77 wherein the duty cycle is at least one of within the range of about 0.1% to about 95%, and about 1% to about 50%.

82. A compound produced in the reactor of claim 1 comprising

(a) at least one neutral, positive, or negative increased binding energy hydrogen species having a binding energy

(i) greater than the binding energy of the corresponding ordinary hydrogen species, or

(ii) greater than the binding energy of any hydrogen species for which the corresponding ordinary hydrogen species is unstable or is not observed because the ordinary hydrogen species' binding energy is less than thermal energies at ambient conditions, or is negative; and

(b) at least one other element.

83. A compound of claim 82 characterized in that the increased binding energy hydrogen species is selected from the group consisting of $H_n$, $H_n^-$, and $H_n^+$ where n is a positive integer, with the proviso that n is greater than 1 when H has a positive charge.

84. A compound of claim 82 characterized in that the increased binding energy hydrogen species is selected from the group consisting of (a) hydride ion having a binding energy that is greater than the binding of ordinary hydride ion (about 0.8 eV) for $p = 2$ up to 23 in which the binding energy is represented by

$$Binding\ Energy = \frac{\hbar^2 \sqrt{s(s+1)}}{8\mu_e a_0^2 \left[\frac{1+\sqrt{s(s+1)}}{p}\right]^2} - \frac{\pi\mu_0 e^2 \hbar^2}{m_e^2}\left(\frac{1}{a_H^3} + \frac{2^2}{a_0^3\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^3}\right)$$

where $p$ is an integer greater than one, $s = 1/2$, $\pi$ is pi, $\hbar$ is Planck's constant bar, $\mu_o$ is the permeability of vacuum, $m_e$ is the mass of the electron, $\mu_e$ is the reduced electron mass given by $\mu_e = \frac{m_e m_p}{\frac{m_e}{\sqrt{\frac{3}{4}}} + m_p}$ where $m_p$ is the mass of the proton, $a_H$ is the radius of the hydrogen atom, $a_o$ is the Bohr radius, and $e$ is the elementary charge; (b) hydrogen atom having a binding energy greater than about 13.6 eV; (c) hydrogen molecule having a first binding energy greater than about 15.3 eV; and (d) molecular hydrogen ion having a binding energy greater than about 16.3 eV.

85. A compound of claim 84 characterized in that the increased binding energy hydrogen species is a hydride ion having a binding energy of about 3, 6.6, 11.2, 16.7, 22.8, 29.3, 36.1, 42.8, 49.4, 55.5, 61.0, 65.6, 69.2, 71.6, 72.4, 71.6, 68.8, 64.0, 56.8, 47.1, 34.7, 19.3, and 0.69 eV.

86. A compound of claim 82 characterized in that the increased binding energy

hydrogen species is a hydride ion having the binding energy:

$$Binding\ Energy = \frac{\hbar^2\sqrt{s(s+1)}}{8\mu_e a_0^2\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^2} - \frac{\pi\mu_0 e^2\hbar^2}{m_e^2}\left(\frac{1}{a_H^3} + \frac{2^2}{a_0^3\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^3}\right)$$

where $p$ is an integer greater than one, $s = 1/2$, $\pi$ is pi, $\hbar$ is Planck's constant bar, $\mu_o$ is the permeability of vacuum, $m_e$ is the mass of the electron, $\mu_e$ is the reduced electron mass given by $\mu_e = \frac{m_e m_p}{\frac{m_e}{\sqrt{\frac{3}{4}}} + m_p}$ where $m_p$ is the mass of the proton, $a_H$ is the radius of the hydrogen atom, $a_o$ is the Bohr radius, and $e$ is the elementary charge.

87. A compound of claim 82 characterized in that the increased binding energy hydrogen species is selected from the group consisting of

(a) a hydrogen atom having a binding energy of about $\frac{13.6\ eV}{\left(\frac{1}{p}\right)^2}$ where p is an integer,

(b) an increased binding energy hydride ion ($H^-$) having a binding energy of about

$$Binding\ Energy = \frac{\hbar^2\sqrt{s(s+1)}}{8\mu_e a_0^2\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^2} - \frac{\pi\mu_0 e^2\hbar^2}{m_e^2}\left(\frac{1}{a_H^3} + \frac{2^2}{a_0^3\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^3}\right)$$

where $p$ is an integer greater than one, $s = 1/2$, $\pi$ is pi, $\hbar$ is Planck's constant bar, $\mu_o$ is the permeability of vacuum, $m_e$ is the mass of the electron, $\mu_e$ is the reduced electron mass given by $\mu_e = \frac{m_e m_p}{\frac{m_e}{\sqrt{\frac{3}{4}}} + m_p}$ where $m_p$ is the mass of the proton, $a_H$ is the radius of the hydrogen atom, $a_o$ is the Bohr radius, and $e$ is the

elementary charge;

(c) an increased binding energy hydrogen species $H_4^+(1/p)$;

(d) an increased binding energy hydrogen species trihydrino molecular ion, $H_3^+(1/p)$, having a binding energy of about $\frac{22.6}{\left(\frac{1}{p}\right)^2}\ eV$ where p is an integer;

(e) an increased binding energy hydrogen molecule having a binding energy of about $\frac{15.3}{\left(\frac{1}{p}\right)^2}\ eV$ ;

(f) an increased binding energy hydrogen molecular ion with a binding energy of about $\frac{16.3}{\left(\frac{1}{p}\right)^2}\ eV$;

(g) $H_2^+(1/p)$; and

(h) $H_2(1/p)$.

88. The reactor of claim 1 wherein the catalyst comprises a chemical or physical process that provides a net enthalpy of $m \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer or $m/2 \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer greater than one.

89. The reactor of claim 1 wherein the catalyst provides a net enthalpy of $m \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer or $m/2 \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer greater than one corresponding to a resonant state energy level of the catalyst that is excited to provide the enthalpy.

90. The reactor of claim 89 wherein preferably $m$ is an integer less than 400.

91. The reactor of claim 1 wherein a catalytic system is provided by the ionization of $t$ electrons from a participating species such as an atom, an ion, a molecule, and an ionic or molecular compound to a continuum energy level such that the sum of the ionization energies of the $t$ electrons is approximately $m \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer or $m/2 \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer greater than

one and $t$ is an integer.

92. The reactor of claim 91 wherein preferably $m$ is an integer less than 400.

93. The reactor of claim 1 wherein the catalyst is provided by the transfer of $t$ electrons between participating ions; the transfer of $t$ electrons from one ion to another ion provides a net enthalpy of reaction whereby the sum of the ionization energy of the electron donating ion minus the ionization energy of the electron accepting ion equals approximately $m \cdot 27.2 \pm 0.5\ eV$ where $m$ is an integer or $m/2 \cdot 27.2 \pm 0.5\ eV$ where $m$ is an integer greater than one and $t$ is an integer.

94. The reactor of claim 93 wherein preferably $m$ is an integer less than 400.

95. The reactor of claim 1 wherein the catalyst comprises $He^{+}$ which absorbs $40.8\ eV$ during the transition from the $n=1$ energy level to the $n=2$ energy level which corresponds to $3/2 \cdot 27.2\ eV$ ($m=3$) that serves as a catalyst for the transition of atomic hydrogen from the $n=1$ ($p=1$) state to the $n=1/2$ ($p=2$) state.

96. The reactor of claim 1 wherein the catalyst comprises $Ar^{2+}$ which absorbs $40.8\ eV$ and is ionized to $Ar^{3+}$ which corresponds to $3/2 \cdot 27.2\ eV$ ($m=3$) during the transition of atomic hydrogen from the $n=1$ ($p=1$) energy level to the $n=1/2$ ($p=2$) energy level.

97. The reactor of claim 1 wherein the catalyst is selected from the group of Li, Be, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Kr, Rb, Sr, Nb, Mo, Pd, Sn, Te, Cs, Ce, Pr, Sm, Gd, Dy, Pb, Pt, $2K^{+}$, $He^{+}$, $Na^{+}$, $Rb^{+}$, $Sr^{+}$, $Fe^{3+}$, $Mo^{2+}$, $Mo^{4+}$, and $In^{3+}$.

98. The reactor of claim 1, wherein the catalyst of atomic hydrogen is capable of providing a net enthalpy of $m \cdot 27.2 \pm 0.5\ eV$ where $m$ is an integer or

$m/2 \cdot 27.2 \ \pm 0.5 \ eV$ where $m$ is an integer greater than one and capable of forming a hydrogen atom having a binding energy of about $\frac{13.6 \ eV}{\left(\frac{1}{p}\right)^2}$ where $p$ is an integer wherein the net enthalpy is provided by the breaking of a molecular bond of the catalyst and the ionization of $t$ electrons from an atom of the broken molecule each to a continuum energy level such that the sum of the bond energy and the ionization energies of the $t$ electrons is approximately $m \cdot 27.2 \ \pm 0.5 \ eV$ where $m$ is an integer or $m/2 \cdot 27.2 \ \pm 0.5 \ eV$ where $m$ is an integer greater than one.

99. The reactor of claim 1 wherein the catalyst comprises at least one of $C_2$, $N_2$, $O_2$, $CO_2$, $NO_2$, and $NO_3$.

100. The reactor of claim 1 wherein the catalyst comprises a molecule in combination with an ion or atom catalyst.

101. The reactor of claim 100 wherein the catalyst comprises at least one molecule selected from the group of $C_2$, $N_2$, $O_2$, $CO_2$, $NO_2$, and $NO_3$ in combination with at least one atom or ion selected from the group of Li, Be, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Kr, Rb, Sr, Nb, Mo, Pd, Sn, Te, Cs, Ce, Pr, Sm, Gd, Dy, Pb, Pt, Kr, $2K^+$, $He^+$, $Na^+$, $Rb^+$, $Sr^+$, $Fe^{3+}$, $Mo^{2+}$, $Mo^{4+}$, $In^{3+}$, $He^+$, $Ar^+$, $Xe^+$, $Ar^{2+}$ and $H^+$, and $Ne^+$ and $H^+$.

102. The reactor of claim 1 wherein the catalyst comprises a neon excimer, $Ne_2^*$, which absorbs 27.21 $eV$ and is ionized to $2Ne^+$, to catalyze the transition of atomic hydrogen from the ($p$) energy level to the ($p+1$) energy level given by

$$27.21 \ eV + Ne_2^* + H\left[\frac{a_H}{p}\right] \rightarrow 2Ne^+ + H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6 \ eV$$

$$2Ne^+ \rightarrow Ne_2^* + 27.21 \ eV$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \to H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV$$

103. The reactor of claim 1 wherein the catalyst comprises helium excimer, $He_2*$, which absorbs 27.21 $eV$ and is ionized to $2He^+$, to catalyze the transition of atomic hydrogen from the $(p)$ energy level to the $(p+1)$ energy level given by

$$27.21\ eV + He_2* + H\left[\frac{a_H}{p}\right] \to 2He^+ + H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV$$

$$2He^+ \to He_2* + 27.21\ eV$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \to H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV$$

104. The reactor of claim 1 wherein the catalyst comprises two hydrogen atoms which absorbs 27.21 $eV$ and is ionized to $2H^+$, to catalyze the transition of atomic hydrogen from the $(p)$ energy level to the $(p+1)$ energy level given by

$$27.21\ eV + 2H\left[\frac{a_H}{1}\right] + H\left[\frac{a_H}{p}\right] \to 2H^+ + 2e^- + H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV$$

$$2H^+ + 2e^- \to 2H\left[\frac{a_H}{1}\right] + 27.21\ eV$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \to H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p]X13.6\ eV$$

105. The reactor of claim 1 wherein a catalytic disproportionation reaction of atomic hydrogen wherein lower-energy hydrogen atoms, hydrinos, can act as catalysts because each of the metastable excitation, resonance excitation, and ionization energy of a hydrino atom is $m\,X\,27.2\ eV$.

106. The reactor of claim 105, wherein the catalytic reaction of a first hydrino atom to a lower energy state affected by a second hydrino atom involves the resonant coupling between the atoms of $m$ degenerate multipoles each having $27.21\ eV$ of potential energy.

107. The reactor of claim 105, wherein the energy transfer of $m\ X\ 27.2\ eV$ from the first hydrino atom to the second hydrino atom causes the central field of the first atom to increase by $m$ and its electron to drop $m$ levels lower from a radius of $\frac{a_H}{p}$ to a radius of $\frac{a_H}{p+m}$.

108. The reactor of claim 105 wherein the second interacting lower-energy hydrogen is either excited to a metastable state, excited to a resonance state, or ionized by the resonant energy transfer.

109. The reactor of claim 105 wherein the resonant transfer may occur in multiple stages.

110. The reactor of claim 109 wherein a nonradiative transfer by multipole coupling may occur wherein the central field of the first increases by $m$, then the electron of the first drops $m$ levels lower from a radius of $\frac{a_H}{p}$ to a radius of $\frac{a_H}{p+m}$ with further resonant energy transfer.

111. The reactor of claim 105 wherein the energy transferred by multipole coupling may occur by a mechanism that is analogous to photon absorption involving an excitation to a virtual level.

112. The reactor of claim 105 wherein the energy transferred by multipole coupling during the electron transition of the first hydrino atom may occur by a mechanism that is analogous to two photon absorption involving a first excitation to a virtual level and a second excitation to a resonant or continuum level.

113. The reactor of claim 1, wherein a catalytic reaction with hydrino catalysts for the transition of $H\left[\frac{a_H}{p}\right]$ to $H\left[\frac{a_H}{p+m}\right]$ induced by a multipole resonance transfer of $m \cdot 27.21\ eV$ and a transfer of $[(p')^2 - (p'-m')^2]\ X\,13.6\ eV - m \cdot 27.2\ eV$ with a resonance state of $H\left[\frac{a_H}{p'-m'}\right]$ excited in $H\left[\frac{a_H}{p'}\right]$ is represented by

$$H\left[\frac{a_H}{p'}\right] + H\left[\frac{a_H}{p}\right] \rightarrow$$
$$H\left[\frac{a_H}{p'-m'}\right] + H\left[\frac{a_H}{p+m}\right] + [((p+m)^2 - p^2) - (p'^2 - (p'-m')^2)]\ X\,13.6\ eV$$

where $p$, $p'$, $m$, and $m'$ are integers.

114. The reactor of claim 1 wherein the catalytic reaction with hydrino catalysts wherein a hydrino atom with the initial lower-energy state quantum number $p$ and radius $\frac{a_H}{p}$ may undergo a transition to the state with lower-energy state quantum number $(p+m)$ and radius $\frac{a_H}{(p+m)}$ by reaction with a hydrino atom with the initial lower-energy state quantum number $m'$, initial radius $\frac{a_H}{m'}$, and final radius $a_H$ that provides a net enthalpy of $m \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer or $m/2 \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer greater than one.

115. The reactor of claim 114 wherein the catalyst reaction of hydrogen-type atom, $H\left[\frac{a_H}{p}\right]$, with the hydrogen-type atom, $H\left[\frac{a_H}{m'}\right]$, that is ionized by the resonant energy transfer to cause a transition reaction is represented by

$$m\,X\,27.21\ eV + H\left[\frac{a_H}{m'}\right] + H\left[\frac{a_H}{p}\right] \rightarrow$$
$$H^+ + e^- + H\left[\frac{a_H}{(p+m)}\right] + [(p+m)^2 - p^2 - (m'^2 - 2m)]X13.6\ eV$$

$$H^+ + e^- \rightarrow H\left[\frac{a_H}{1}\right] + 13.6\ eV$$

And, the overall reaction is

$$H\left[\frac{a_H}{m'}\right] + H\left[\frac{a_H}{p}\right] \rightarrow$$
$$H\left[\frac{a_H}{1}\right] + H\left[\frac{a_H}{(p+m)}\right] + \left[2pm + m^2 - m'^2\right]X13.6\ eV + 13.6\ eV$$

116. The reactor of claim 1 wherein the catalyst comprises a mixture of a first catalyst and a source of a second catalyst.

117. The reactor of claim 116 wherein the first catalyst produces the second catalyst from the source of the second catalyst.

118. The reactor of claim 117 wherein the energy released by the catalysis of hydrogen by the first catalyst produces a plasma in the energy cell.

119. The reactor claim 117 wherein the energy released by the catalysis of hydrogen by the first catalyst ionizes the source of the second catalyst to produce the second catalyst.

120. The reactor of claim 116 wherein the first catalyst provides a net enthalpy of $m \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer or $m/2 \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer greater than one corresponding to a resonant state energy level of the catalyst that is excited to provide the enthalpy.

121. The reactor of claim 116, wherein the second catalyst is selected from the group of helium, neon, or argon and the second catalyst is selected from the group of $He^+$, $Ne^+$, and $Ar^+$ wherein the catalyst ion is generated from the corresponding atom by a plasma created by catalysis of hydrogen by the first catalyst.

122. The reactor of claim 1 wherein the cell comprises at least one of the group of a

microwave cell, plasma torch cell, radio frequency (RF) cell, glow discharge cell, barrier electrode cell, plasma electrolysis cell, a pressurized gas cell, filament cell or rt-plasma cell, and a combination of a glow discharge cell and a microwave cell and or RF plasma cell.

123. The reactor of claim 1 comprising a vessel having a chamber capable of containing a vacuum or pressures greater than atmospheric, a source of atomic hydrogen comprising a means to dissociate molecular hydrogen to atomic hydrogen, and a means to heat the source of catalyst capable of providing a net enthalpy of $m \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer or $m/2 \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer greater than one.

124. The reactor of claim 1 wherein the source of atomic hydrogen comprises a hydrogen dissociator.

125. The reactor of claim 124, wherein the hydrogen dissociator comprises a filament.

126. The reactor of claim 125, wherein the filament comprises a tungsten filament.

127. The reactor of claim 124, further comprising a heater to heat the catalyst to form a gaseous catalyst.

128. The reactor of claim 127 wherein the catalyst comprises at least one of potassium, rubidium, cesium and strontium metal, nitrate, or carbonate.

129. The reactor of claim 1 further comprising a hydrogen supply tube and a hydrogen supply passage to supply hydrogen gas to the vessel.

130. The reactor of claim 1 further comprising a hydrogen flow of hydrogen flow controller and valve to control the flow of hydrogen to the chamber.

131. The reactor of claim 1 comprising a plasma gas, a plasma gas supply, and a plasma gas passage.

132. The reactor of claim 1 comprising lines, valves, and flow regulators such that the plasma gas flows from the plasma gas supply via the plasma gas passage into the vessel.

133. The reactor of claim 1 wherein the plasma gas flow controller and control valve control the flow of plasma gas into the vessel.

134. The reactor of claim 1 further comprising a hydrogen-plasma-gas mixer and mixture flow regulator.

135. The reactor of claim 1 further comprising a hydrogen-plasma-gas mixture, a hydrogen-plasma-gas mixer, and a mixture flow regulator which control the composition of the mixture and the its flow into the vessel.

136. The reactor of claim 1 further comprising a passage for the flow of the hydrogen-plasma-gas mixture into the vessel.

137. The reactor of claim 136, wherein the plasma gas comprises at least one of the group of helium, neon, or argon.

138. The reactor of claim 136, wherein the plasma gas is a source of the catalyst selected from the group of $He^+$, $Ne^+$, and $Ar^+$.

139. The reactor of claim 1 wherein the plasma gas is a source of catalyst and the hydrogen-plasma-gas mixture flows into the plasma and becomes catalyst and atomic hydrogen in the vessel.

140. The reactor of claim 1 further comprising a vacuum pump and vacuum lines.

141. The reactor of claim 140, wherein the vacuum pump evacuates the vessel through the vacuum lines.

142. The reactor of claim 1 further comprising a gas flow means to provide that the reactor is operated under flow conditions with the hydrogen and the catalyst supplied continuously from the catalyst source and the hydrogen source.

143. The reactor of claim 1 further comprising a catalyst reservoir and a catalyst supply passage for the passage of the gaseous catalyst from the reservoir to the vessel.

144. The reactor of claim 1 further comprising a catalyst reservoir heater and a power supply to heat the catalyst in the catalyst reservoir to provide the gaseous catalyst.

145. The reactor of claim 144, wherein the catalyst reservoir heater comprises a temperature control means wherein the vapor pressure of the catalyst is controlled by controlling the temperature of the catalyst reservoir.

146. The reactor of claim 1 wherein the catalyst is one selected from the group of Li, Be, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Kr, Rb, Sr, Nb, Mo, Pd, Sn, Te, Cs, Ce, Pr, Sm, Gd, Dy, Pb, Pt, $He^{+}$, $Na^{+}$, $Rb^{+}$, $Sr^{+}$, $Fe^{3+}$, $Mo^{2+}$, $Mo^{4+}$, $K^{+}/K^{+}$, and $In^{3+}$.

147. The reactor of claim 1 further comprising a chemically resistant open container such as a ceramic boat located inside the vessel which contains the catalyst.

148. The reactor of claim 1 further comprising a heater to maintain an elevated cell temperature such that the catalyst in the boat is sublimed, boiled, or volatilized into the gas phase.

149. The reactor of claim 148 wherein the catalyst boat further comprises a boat heater, and a power supply that heats the catalyst in the catalyst boat to provide the gaseous catalyst to the vessel.

150. The reactor of claim 149, wherein the catalyst boat heater comprises a temperature control means wherein the vapor pressure of the catalyst is controlled by controlling the temperature of the catalyst boat.

151. The reactor of claim 1 further comprising a lower-energy hydrogen species and lower-energy hydrogen compound trap.

152. The reactor of claim 1 further comprising a vacuum pump in communication with the trap to cause a pressure gradient from the vessel to the trap to cause gas flow and transport of the lower-energy hydrogen species or lower-energy hydrogen compound.

153. The reactor of claim 1 further comprising a passage from the vessel to the trap and a vacuum line from the trap to the pump, and further comprising valves to and from the trap.

154. The reactor of claim 1 wherein the vessel comprises a stainless steel alloy cell, a molybdenum cell, a tungsten cell, a glass, quartz, or ceramic cell.

155. The reactor of claim 1 further comprising at least one of the group of an aspirator, atomizer, or nebulizer to form an aerosol of the source of catalyst.

156. The reactor of claim 1 wherein the aspirator, atomizer, or nebulizer injects the source of catalyst or catalyst directly into the plasma.

157. The reactor of claim 1 further comprising a plasma gas and a catalyst that is agitated from a source and supplied to the vessel through a flowing gas stream.

158. The reactor of claim 157, wherein the flowing gas stream comprises hydrogen gas or plasma gas which may be an additional source of catalyst.

159. The reactor of claim 158 wherein the additional source of catalyst comprises helium, neon, or argon.

160. The reactor of claim 1 wherein the catalyst is dissolved or suspended in a liquid medium such as water and solution or suspension is aerosolized.

161. The reactor of claim 160 wherein the medium is contained in the catalyst reservoir.

162. The reactor of claim 160 wherein the solution or suspension containing catalyst is transported to the vessel by a carrier gas.

163. The reactor of claim 162 wherein the carrier gas comprises at least one of the group of hydrogen, helium, neon, or argon.

164. The reactor of claim 162, wherein the carrier gas comprises at least one of the group of helium, neon, or argon which serves as a source of catalyst and is ionized by the plasma to form at least one of the catalysts $He^+$, $Ne^+$, and $Ar^+$.

165. The reactor of claim 1 wherein the nonthermal plasma temperature is maintained in the range of 5,000-5,000,000 °C.

166. The reactor of claim 1 wherein the cell temperature is maintained above that of the catalyst reservoir which serves as a controllable source of catalyst.

167. The reactor of claim 1 wherein the cell temperature is maintained above that of the catalyst boat which serves as a controllable source of catalyst.

168. The reactor of claim 1 wherein a stainless steel alloy cell is preferably maintained in the temperature range of 0-1200°C.

169. The reactor of claim 1 wherein a molybdenum cell is preferably maintained in the temperature range of 0-1800 °C.

170. The reactor of claim 1 wherein a tungsten cell is preferably maintained in the temperature range of 0-3000 °C.

171. The reactor of claim 1 wherein a glass, quartz, or ceramic cell is preferably

maintained in the temperature range of 0-1800 °C.

172. The reactor of claim 1 wherein molecular and atomic hydrogen partial pressures in the vessel is maintained in the range of 1 mtorr to 100 atm.

173. The reactor of claim 1 wherein molecular and atomic hydrogen partial pressures in the vessel is maintained in the range of 100 mtorr to 20 torr.

174. The reactor of claim 1 wherein catalyst partial pressure in the vessel is maintained in the range of 1 mtorr to 100 atm.

175. The reactor of claim 1 wherein the catalyst partial pressure in the vessel is maintained in the range of 100 mtorr to 20 torr.

176. The reactor of claim 1 wherein the flow rate of the plasma gas is 0.00000001 to 1 standard liters per minute per $cm^3$ of vessel volume.

177. The reactor of claim 1 wherein the flow rate of the plasma gas is 0.001 to 10 sccm per $cm^3$ of vessel volume.

178. The reactor of claim 1 wherein the flow rate of the hydrogen gas is 0.00000001 to 1 standard liters per minute per $cm^3$ of vessel volume.

179. The reactor of claim 1 wherein the flow rate of the hydrogen gas is 0.001-10 sccm per $cm^3$ of vessel volume.

180. one selected from helium, neon, and argon comprising a composition of the plasma gas in the range of 99 to 1%.

181. The reactor of claim 179, wherein the hydrogen-plasma-gas mixture comprises one selected from helium, neon, and argon comprising a composition of the plasma gas in the range of 99 to 95%.

182. The reactor of claim 179 wherein the flow rate of the hydrogen-plasma-gas mixture is 0.00000001 to 1 standard liters per minute per $cm^3$ of vessel volume.

183. The reactor of claim 179 wherein the flow rate of the hydrogen-plasma-gas mixture is 0.001-10 sccm per $cm^3$ of vessel volume.

184. The reactor of claim 1 further comprising a selective valve for removal of lower-energy hydrogen products.

185. The reactor of claim 1 wherein the selectively removed lower-energy hydrogen products comprises dihydrino molecules.

186. The reactor of claim 1 further comprising a cold wall or cryotrap to which at least one of increased binding energy hydrogen compounds and dihydrino gas are cryopumped.

187. The reactor of claim 1 comprises at least on of the group of an rt-plasma cell and a plasma electrolysis reactor, a barrier electrode reactor, an RF plasma reactor, a pressurized gas energy reactor, a gas discharge energy reactor, a microwave cell energy reactor, and a combination of a glow discharge cell and a microwave and or RF plasma reactor wherein the power supplied to the cell is pulsed or intermittent.

188. The reactor of claim 187 wherein the frequency of alternating power may be within the range of at least one of about 0.001 Hz to 100 GHz, about 60 Hz to 10 GHz, and about 10 MHz to 10 GHz.

189. The reactor of claim 187 further comprising two electrodes wherein one or more electrodes are at least one of in direct contact with the plasma and the electrodes may be separated from the plasma by a dielectric barrier wherein the peak voltage may be within the range of at least one of about 1 V to 10 MV, about 10 V to 100 kV, and about 100 V to 500 V.

190. The reactor of claim 189 further comprising at least one antenna to deliver power to the plasma.

191. The reactor of claim 1 wherein the cell comprises a glow discharge cell comprising a vessel having a chamber capable of containing a vacuum or pressures greater than atmospheric, a source of atomic hydrogen, a cathode, an anode, a discharge power source to produce a glow discharge plasma, a source of atomic hydrogen, a source of catalyst, and a vacuum pump.

192. The reactor of claim 191 wherein the discharge current is intermittent or pulsed.

193. The reactor of claim 192 wherein an offset voltage is between 0.5 and 500 V or the offset voltage is set to provide a field between 1 V/cm to 10 V/cm.

194. The reactor of claim 192 wherein the pulse frequency is between 0.1 Hz and 100 MHz and a duty cycle is between 0.1% and 95%.

195. The reactor of claim 191 comprising a hollow cathode comprising a compound electrode comprising multiple electrodes in series or parallel that may occupy a substantial portion of the volume of the reactor.

196. The reactor of claim 195 comprising multiple hollow cathodes in parallel so that a desired electric field is produced in a large volume to generate a substantial power level.

197. The reactor of claim 196 comprising an anode and at least one of the group of multiple concentric hollow cathodes each electrically isolated from the common anode and multiple parallel plate electrodes connected in series.

198. The reactor of claim 191 wherein the discharge voltage is at least one of within the range of about 1000 to about 50,000 volts; the current is at least one of within the range of about 1 $\mu$A to about 1 A and about 1 mA.

199. The reactor of claim 191 wherein the power is applied as an alternating current (AC).

200. The reactor of claim 199 wherein the frequency is at least within the range of about 0.001 Hz to 1 GHz, about 60 Hz to 100 MHz, and about 10 to 100 MHz.

201. The reactor of claim 199 comprising two electrodes wherein one or more electrodes are in direct contact with the plasma.

202. The reactor of claim 201 wherein the peak voltage is at least within the range of about 1 V to 10 MV, about 10 V to 100 kV, and about 100 V to 500 V.

203. The reactor of claim 191 comprising an intermittent or pulsed current wherein the offset voltage is at least one of within the range of about 0.5 to about 500 V, is set to provide a field of about 0.1 V/cm to about 50 V/cm, and is set to provide a field between about 1 V/cm to about 10 V/cm;the peak voltage is at least one of within the range of about 1 V to 10 MV, about 10 V to 100 kV, and about 100 V to 500 V; the pulse frequency is within the range of about 1 to about 200 Hz, and the duty cycle is at least one of within the range of about 0.1% to about 95% and about 1% to about 50%.

204. The reactor of claim 1 wherein the cell comprises a microwave plasma forming gas cell comprising a vessel having a chamber capable of containing a vacuum or pressures greater than atmospheric, a source of atomic hydrogen comprising plasma dissociation of molecular hydrogen, a source of microwave power, and a source of catalyst capable of providing a net enthalpy of $m \cdot 27.2 \ \pm 0.5\ eV$ where $m$ is an integer or $m/2 \cdot 27.2 \ \pm 0.5\ eV$ where $m$ is an integer greater than one.

205. The reactor of claim 204 wherein the source of microwave power is a microwave generator, a tunable microwave cavity, waveguide, and a RF transparent window.

206. The reactor of claim 204 wherein the source of microwave power is a microwave generator, a tunable microwave cavity, waveguide, and an antenna.

207. The reactor of claim 204 wherein the microwaves are tuned by a tunable microwave cavity, carried by waveguide, and are delivered to the vessel though the RF transparent window.

208. The reactor of claim 204 wherein the microwaves are tuned by a tunable microwave cavity, carried by waveguide, and are delivered to the vessel though the antenna.

209. The reactor of claim 208, wherein the waveguide is either inside or outside of the cell.

210. The reactor of claim 208, wherein the antenna is either inside or outside of the cell.

211. The reactor of claim 204, wherein the microwave generator comprises at least one of the group of traveling wave tubes, klystrons, magnetrons, cyclotron resonance masers, gyrotrons, and free electron lasers.

212. The reactor of claim 205, wherein the microwave window comprises an Alumina or quartz window.

213. The reactor of claim 204 wherein the vessel is a microwave resonator cavity.

214. The reactor of claim 204 wherein the cavity is at least one of the group of Evenson, Beenakker, McCarrol, and cylindrical cavity.

215. The reactor of claim 204 comprising a vessel comprising a cavity that is a reentrant microwave cavity and the source of microwave power that excites a plasma in the reentrant cavity.

216. The reactor of claim 215, wherein the reentrant cavity is an Evenson microwave cavity.

217. The reactor of claim 204 wherein the microwave frequency of the source of microwave power is selected to efficiently form atomic hydrogen from molecular hydrogen.

218. The reactor of claim 204 wherein the microwave frequency of the source of microwave power is selected to efficiently form ions that serve as catalysts from a source of catalyst.

219. The reactor of claim 218, wherein the source of catalyst and catalyst comprises helium, neon, and argon and $He^+$, $Ne^+$, and $Ar^+$, respectively.

220. The reactor of claim 204 wherein the microwave frequency of the source of microwave power is in the range of 1 MHz to 100 GHz.

221. The reactor of claim 204 wherein the microwave frequency of the source of microwave power is in the range of 50 MHz to 10 GHz.

222. The reactor of claim 204 wherein the microwave frequency of the source of microwave power is in the range of 75 MHz $\pm$ 50 MHz.

223. The reactor of claim 204 wherein the microwave frequency of the source of microwave power is in the range of 2.4 GHz $\pm$ 1 GHz.

224. The reactor of claim 204 wherein the catalyst is atomic hydrogen wherein the hydrogen pressure of the hydrogen microwave plasma is within at least one of the range of about 1 mtorr to about 100 atm, about 100 mtorr to about 1 atm, and about 100 mtorr to about 10 torr; the microwave power density is within at least one of the range of about 0.01 W to about 100 W/$cm^3$ vessel volume, andthe hydrogen flow rate is within at least one of the range of about 0-1 standard liters per minute per $cm^3$ of vessel volume and about 0.001-10 sccm per $cm^3$ of vessel volume.

225. The reactor of claim 204 wherein the power density of the source of plasma power is 0.01 W to 100 W/$cm^3$ vessel volume.

226. The reactor of claim 204 wherein the cell is a microwave resonator cavity.

227. The reactor of claim 204 wherein the source of microwave supplies sufficient microwave power density to the cell to ionize a source of catalyst to form the catalyst.

228. The reactor of claim 227, wherein the source of catalyst comprises as at least one of helium, neon, or argon to form a catalyst such as $He^+$, $Ne^+$, and $Ar^+$, respectively.

229. The reactor of claim 204 wherein the microwave power source forms a nonthermal plasma.

230. The reactor of claim 229 wherein the microwave power source or applicator is an antenna, waveguide, or cavity.

231. The reactor of claim 227 wherein the microwave power source forms a nonthermal plasma.

232. The reactor of claim 231 wherein the microwave power source or applicator is an antenna, waveguide, or cavity.

233. The reactor of claim 232 wherein the species corresponding to the source of catalyst have a higher temperature than that at thermal equilibrium.

234. The reactor of claim 233 wherein the source of catalyst comprises at least one selected from the group of helium, neon, and argon atoms.

235. The reactor of claim 234 wherein higher energy states such as ionized states of the source of catalyst are predominant over that of hydrogen compared to a

corresponding thermal plasma wherein excited states of hydrogen are predominant.

236. The reactor of claim 204 comprising a plurality of sources of microwave power.

237. The reactor of claim 236 wherein the plurality of microwave sources are used simultaneously.

238. The reactor of claim 247 wherein the plurality of microwave sources comprise Evenson cavities.

239. The reactor of claim 204 wherein the reactor forms a nonthermal plasma maintained by multiple Evenson cavities operated in parallel.

240. The reactor of claim 239 that is cylindrical and comprises a quartz cell with Evenson cavities spaced along the longitudinal axis.

241. The reactor of claims 204 wherein the frequency of the alternating power is at least one of within the range of about 100 MHz to 100 GHz, about 100 MHz to 10 GHz, and about 1 GHz to 10 GHz or about 2.4 GHz $\pm$ 1 GHz, the pulse frequency is at least one of within the range of about 0.1 Hz to about 100 MHz, about 10 to about 10,000 Hz, and about 100 to about 1000 Hz; the duty cycle is at least one of within the range of about 0.001% to about 95% and about 10%; the peak power density of the pulses into the plasma is at least one of within the range of about 1 $W/cm^3$ to 1 $GW/cm^3$, about 10 $W/cm^3$ to 10 $MW/cm^3$, and about 100 $W/cm^3$ to 10 $kW/cm^3$, and the average power density into the plasma is at least one of within the range of about 0.001 $W/cm^3$ to 1 $kW/cm^3$, about 0.1 $W/cm^3$ to 100 $W/cm^3$, and about 1 $W/cm^3$ to 10 $W/cm^3$.

242. The reactor of claim 241 wherein the source microwaves comprise at least one from the group of traveling wave tubes, klystrons, magnetrons, cyclotron resonance masers, gyrotrons, and free electron lasers.

243. The reactor of claim 241 wherein the power is amplified with an amplifier.

244. The reactor of claim 241 wherein the pulsed microwaves power source comprises at least one of a magnetron with a pulsed high voltage to the magnetron and a pulsed magnetron current that may be supplied by a pulse of electrons from an electron source such as an electron gun.

245. The reactor of claim 1 comprising an RF plasma forming gas cell comprising a vessel, a source of atomic hydrogen from RF plasma dissociation of molecular hydrogen, a source of RF power, and a catalyst capable of providing a net enthalpy of $m \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer or $m/2 \cdot 27.2\ \pm 0.5\ eV$ where $m$ is an integer greater than one.

246. The reactor of claim 245 wherein the RF power is capacitively or inductively coupled to the cell.

247. The reactor of claim 245 further comprising two electrodes.

248. The reactor of claim 245 comprising a coaxial cable connected to the a powered electrode by a coaxial center conductor.

249. The reactor of claim 245 comprising a coaxial center conductor connected to an external source coil which is wrapped around the cell.

250. The reactor of claim 249 wherein the coaxial center conductor connected to an external source coil which is wrapped around the cell terminates without a connection to ground.

251. The reactor of claim 249 wherein the coaxial center conductor connected to an external source coil which is wrapped around the cell is connect to ground.

252. The reactor of claim 251 comprising two electrodes wherein the electrodes are parallel plates.

253. The reactor of claim 252 wherein the one of the parallel plate electrodes is powered and the other is connected to ground.

254. The reactor of claim 247 wherein the cell comprises a Gaseous Electronics Conference (GEC) Reference Cell or modification thereof.

255. The reactor of claim 245 wherein the RF power is at 13.56 MHz.

256. The reactor of claim 249 wherein at least one wall of the cell wrapped with the external coil is at least partially transparent to the RF excitation.

257. The reactor of claim 245 wherein the RF frequency is preferably in the range of about 100 Hz to about 100 GHz.

258. The reactor of claim 245 wherein the RF frequency is preferably in the range of about 1 kHz to about 100 MHz.

259. The reactor of claim 245 wherein the RF frequency is preferably in the range of about 13.56 MHz $\pm$ 50 MHz or about 2.4 GHz $\pm$ 1 GHz.

260. The reactor of claim 1 comprising an inductively coupled toroidal plasma cell comprising a vessel, a source of atomic hydrogen comprising RF plasma dissociation of molecular hydrogen, a source of RF power, and a catalyst capable of providing a net enthalpy of $m \cdot 27.2 \ \pm 0.5\ eV$ where $m$ is an integer or $m/2 \cdot 27.2 \ \pm 0.5\ eV$ where $m$ is an integer greater than one.

261. The reactor of claim 260 comprising the Astron system of Astex Corporation described in US Patent No. 6,150,628.

262. The reactor of claim 260 comprising a primary of a transformer circuit.

263. The reactor of claim 260 comprising a primary of a transformer circuit driven by a

radio frequency power supply.

264. The reactor of claim 260 comprising a primary of a transformer circuit wherein the plasma is a closed loop which acts at as a secondary of the transformer circuit.

265. The reactor of claim 260 wherein the RF frequency is in the range of about 100 Hz to about 100 GHz.

266. The reactor of claim 260 wherein the RF frequency is in the range of about 1 kHz to about 100 MHz.

267. The reactor of claim 260 wherein the RF frequency is in the range of about 13.56 MHz ± 50 MHz or about 2.4 GHz ± 1 GHz.

268. The reactor of claim 245 wherein the frequency of the RF power is at least one of in the range of about 100 Hz to about 100 MHz, about 1 kHz to about 50 MHz, and about 13.56 MHz ± 50 MHz; the pulse frequency is at least one of about 0.1 Hz to about 100 MHz, about 10 Hz to about 10 MHz, about 100 Hz to about 1 MHz; the duty cycle is at least one of in the range of about 0.001% to about 95% and about 0.1% to about 10%; the peak power density of the pulses into the plasma is at least one of within the range of about 1 $W/cm^3$ to 1 $GW/cm^3$ about 10 $W/cm^3$ to 10 $MW/cm^3$, and about 100 $W/cm^3$ to 10 $kW/cm^3$, and the average power density into the plasma is at least one of within the range of about 0.001 $W/cm^3$ to 1 $kW/cm^3$, about 0.1 $W/cm^3$ to 100 $W/cm^3$, and about 1 $W/cm^3$ to 10 $W/cm^3$.

269. The reactor of claim 1 wherein the cell comprises a plasma forming electrolytic cell comprising a vessel, a cathode, an anode, an electrolyte, a high voltage electrolysis power supply, and a catalyst capable of providing a net enthalpy of $m \cdot 27.2 \ \pm 0.5\ eV$ where $m$ is an integer or $m/2 \cdot 27.2 \ \pm 0.5\ eV$ where $m$ is an integer greater than one.

270. The reactor of claim 269 wherein the voltage is in the range 10-50 kV and the current density in the range of 1 to 100 A/cm$^2$.

271. The reactor of claim 269, wherein the cathode comprises tungsten.

272. The reactor of claim 269 wherein the anode comprises platinum.

273. The reactor of claim 269 wherein the catalyst comprises at least one selected from the group of Li, Be, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Kr, Rb, Sr, Nb, Mo, Pd, Sn, Te, Cs, Ce, Pr, Sm, Gd, Dy, Pb, Pt, $He^+$, $Na^+$, $Rb^+$, $Sr^+$, $Fe^{3+}$, $Mo^{2+}$, $Mo^{4+}$, $K^+/K^+$, and $In^{3+}$.

274. The reactor of claim 269 wherein the catalyst is formed from a source of catalyst.

275. The reactor of claim 274 wherein the source of catalyst comprises at least one selected from the group of Li, Be, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Kr, Rb, Sr, Nb, Mo, Pd, Sn, Te, Cs, Ce, Pr, Sm, Gd, Dy, Pb, Pt, $He^+$, $Na^+$, $Rb^+$, $Sr^+$, $Fe^{3+}$, $Mo^{2+}$, $Mo^{4+}$, $In^{3+}$ and $K^+/K^+$.

276. The reactor of claim 275 wherein the plasma electrolysis discharge voltage within the range of about 1000 to about 50,000 volts, the current into the electrolyte is at least one of within the range of about 1 $\mu$A/$cm^3$ to about 1 A/$cm^3$ and about 1 mA/$cm^3$, the offset voltage is below that which causes electrolysis such as within the range of about 0.001 to about 1.4 V, the peak voltage at least one of within the range of about 1 V to 10 MV, about 2 V to 100 kV, and about 2 V to 1 kV, the pulse frequency is at least one of within the range of about 0.1 Hz to about 100 MHz and about 1 to about 200 Hz, and the duty cycle is at least one of within the range of about 0.1% to about 95% and about 1% to about 50%.

277. The reactor of claim 1 wherein the cell comprises a radio frequency (RF) barrier electrode discharge cell comprising a vessel, a source of atomic hydrogen from the RF plasma dissociation of molecular hydrogen, a source of RF power, a cathode,

an anode, and a catalyst capable of providing a net enthalpy of $m \cdot 27.2 \ \pm 0.5 \ eV$ where $m$ is an integer or $m/2 \cdot 27.2 \ \pm 0.5 \ eV$ where $m$ is an integer greater than one.

278. The reactor of claim 277 wherein at least one of the cathode and the anode is shielded by a dielectric barrier.

279. The dielectric barrier of claim 278 comprising at least one of the group of glass, quartz, Alumina, and ceramic.

280. The reactor of claim 277 wherein the RF power may be capacitively coupled to the cell.

281. The reactor of claim 277 wherein the electrodes are external to the cell.

282. The reactor of claim 277 wherein a dielectric layer separates the electrodes from the cell wall.

283. The reactor of claim 277 wherein the high driving voltage may be AC and may be high frequency.

284. The reactor of claim 277 wherein the RF source of power comprises a driving circuit comprising a high voltage power source which is capable of providing RF and an impedance matching circuit.

285. The reactor of claim 277 wherein the frequency is in the range 100 Hz to 10 GHz.

286. The reactor of claim 277 wherein the frequency is in the range 1 kHz to 1 MHz.

287. The reactor of claim 277 wherein the frequency is in the range 5-10 kHz.

288. The reactor of claim 277 wherein the voltage is in the range 100 V to 1 MV.

289. The reactor of claim 277 wherein the voltage is in the range 1 kV to 100 kV.

290. The reactor of claim 277 wherein the voltage is in the range 5 to 10 kV.

291. The reactor of claim 277 wherein the frequency is at least one of within the range of about 100 Hz to about 10 GHz, about 1 MHz, and about 5-10 kHz, and the voltage is at least one of within the range of about 100 V to about 1 MV, about 1 kV to about 100 kV, and about 5 to about 10 kV.

292. The reactor of claim 1 wherein the plasma gas is at least one of helium, neon, and argon corresponding to a source of the catalysts $He^{+}$, $Ne^{+}$, and $Ar^{+}$, respectively.

293. The reactor of claim 1 wherein hydrogen is flowed into the plasma cell separately or as a mixture with other plasma gases such as those that serve as sources of catalysts.

294. The reactor of claim 293 wherein the flow rate of the catalyst gas or hydrogen-catalyst gas mixture such as at least one gas selected for the group of hydrogen, argon, helium, argon-hydrogen mixture, helium-hydrogen mixture is at least one of within the range of about 0.00000001 to 1 standard liters per minute per $cm^3$ of vessel volume, and about 0.001-10 sccm per $cm^3$ of vessel volume.

295. The reactor of claim 294 wherein the percentage of the source of catalyst gas in a helium, neon, or argon-hydrogen mixture is at least one of within the range of about 99.99 to about .01 %, about 99 to about 1 %, and about 99 to about 95%.

296. A method for producing power and lower-energy-hydrogen species and compounds comprising the steps of:

providing a vessel, a source of atomic hydrogen, a source of pulsed or intermittent power, and a catalyst capable of providing a net enthalpy of $m \cdot 27.2 \ \pm 0.5\ eV$ where $m$ is an integer or $m/2 \cdot 27.2 \ \pm 0.5\ eV$ where $m$ is an integer greater than one;

forming a plasma in the vessel with the source of power;

forming atomic hydrogen in the plasma;

reacting the catalyst with the atomic hydrogen to form lower-energy-hydrogen species and compounds.

297. The method for producing power and lower-energy-hydrogen species and compounds of claim 296 further comprising the steps of flowing a plasma gas that is a source of catalyst into the vessel.

298. The method for producing power and lower-energy-hydrogen species and compounds of claim 297 further comprising controlling the power by controlling the amount of gaseous catalyst.

299. The method for producing power and lower-energy-hydrogen species and compounds of claim 298 wherein the amount of gaseous catalyst is controlled by controlling the plasma gas flow rate.

300. The method for producing power and lower-energy-hydrogen species and compounds of claim 297 wherein the power is controlled by controlling the amount of hydrogen.

301. The method for producing power and lower-energy-hydrogen species and compounds of claim 300 wherein the power is controlled by controlling the flow of hydrogen from the source of hydrogen.

302. The method for producing power and lower-energy-hydrogen species and compounds of claim 300 wherein the power is controlled by controlling the flow of hydrogen and plasma gas and the ratio of hydrogen to plasma gas in a mixture.

303. The method for producing power and lower-energy-hydrogen species and compounds of claim 297 wherein the source of catalyst is at least one selected from the group of helium, neon, or argon which provides catalysts $He^+$, $Ne^+$, and $Ar^+$ respectively.

304. The method for producing power and lower-energy-hydrogen species and compounds of claim 302 wherein the power is controlled by controlling the hydrogen flow rate, plasma gas flow rate, and hydrogen-plasma-gas flow rate with at least one of the group of a flow regulator, a hydrogen-plasma-gas mixer, flow rate controllers, and valves.

305. The method for producing power and lower-energy-hydrogen species and compounds of claim 296 wherein the power is controlled by controlling the temperature of the plasma with the power supplied by the source of input power.

306. The method for producing power and lower-energy-hydrogen species and compounds of claim 296 further comprising the steps of providing a source of catalyst from a catalyst reservoir.

307. The method for producing power and lower-energy-hydrogen species and compounds of claim 306 wherein the step of providing a source of catalyst from a catalyst reservoir further comprises the steps of controlling the temperature of the catalyst from a catalyst reservoir to control its vapor pressure.

308. The method for producing power and lower-energy-hydrogen species and compounds of claim 296 further comprising the steps of providing a source of catalyst from a catalyst boat.

309. The method for producing power and lower-energy-hydrogen species and compounds of claim 308 further comprising the steps of controlling the temperature of the catalyst from a catalyst boat to control its vapor pressure.

310. The method for producing power and lower-energy-hdyrogen species and compounds of claim 296 wherein an input power is reduced by using an intermittent or pulsed power source.

311. The method for producing power and lower-energy-hdyrogen species and compounds of claim 310 wherein the intermittent or pulsed power source provides

a time period wherein the field is set to a desired strength by an offset DC, audio, RF, or microwave voltage or electric and magnetic fields.

312. The method for producing power and lower-energy-hdyrogen species and compounds of claim 311 wherein the field is set to a desired strength during a time period by an offset DC, audio, RF, or microwave voltage or electric and magnetic fields that is below that required to maintain a discharge.

313. The method for producing power and lower-energy-hdyrogen species and compounds of claim 311 wherein the desired field strength during a low-field or nondischarge period optimizes the energy match between the catalyst and the atomic hydrogen.

314. The method for producing power and lower-energy-hdyrogen species and compounds of claim 310 wherein the intermittent or pulsed power source further comprises a means to adjust the pulse frequency and duty cycle to optimize the power balance.

315. The method for producing power and lower-energy-hdyrogen species and compounds of claim 314 wherein the pulse frequency and duty cycle is adjusted to optimize the power balance by optimizing the reaction rate versus the input power.

316. The method for producing power and lower-energy-hdyrogen species and compounds of claim 315 wherein the pulse frequency and duty cycle is adjusted to optimize the power balance by optimizing the reaction rate versus the input power by controlling the amount of catalyst and atomic hydrogen generated by the discharge decay during the low-field or nondischarge period wherein the concentrations are dependent on the pulse frequency, duty cycle, and the rate of plasma decay.